Photography of Bullets in Flight.

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INSTANTANEOUS photography by means of an electric spark provides the investigator of high-speed phenomena with a most valuable source of data. Such photographs are of the shadow variety, the bullet shadow being projected upon a photographic plate by a spark of great intensity and short duration. If the bullet is moving with a speed equal to or greater than that of sound, it propagates from both its nose and base a compressional wave. Light from the photographing spark in passing through the denser atmosphere of the compressional wave is refracted as by a lens, so that the wave front is also projected upon the photographic plate with the bullet. The method lends itself readily to the investigation of a projectile's stability at various points along its trajectory and to many allied problems of exterior ballistics. Instructive photographs of the recoil and shell ejection of automatic rifles, pistols, and machine guns may also be obtained in this manner.

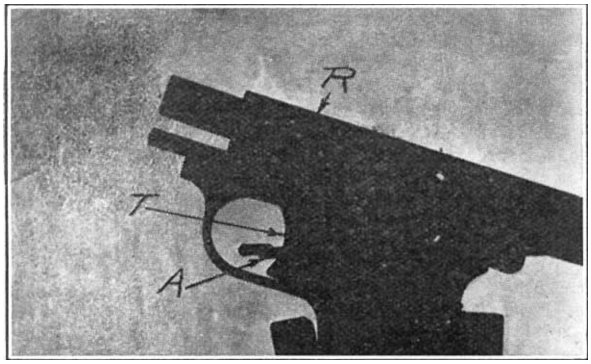

FIG. 1.—Automatic pistol in position of extreme recoil, empty cartridge case not yet ejected.
T = trigger; R = receiver; A = arm operating trigger.

Among the most important of the early contributions in this field of research are the admirable spark photographs by Prof. C. V. Boys (NATURE, Vol. 47, pp. 415 and 440), who greatly simplified the elaborate apparatus of Prof. E. Mach. In Prof. Boys's apparatus the bullet was employed to close the spark circuit, and this method has been followed in experiments which have been carried on since that time, so far as the present writer is aware.

In the method described in this article the setting-off or triggering of the electric spark by which the photographs are taken is controlled by the compressional wave produced by the flight of the bullet, so that no wires or other portions of the apparatus need appear on the plates. Since the sound wave is used to trigger the photographing spark, the position of the rifle firing the bullet may be varied at will without affecting the functioning of the apparatus, the only requirement being that the bullet shall have a speed greater than that of sound. When the speed of the bullet is less than that of sound the muzzle blast may be used to trigger the spark. In such cases the rifle must not be moved.

In Prof. Boys's type of apparatus the photographing spark is set off by the closing of a secondary gap by the bullet itself. In the present apparatus a much more powerful spark may be used than would otherwise be possible, because the potential available for the photographing spark is not limited by the dielectric strength of some trigger gap of fixed and small dimensions.

The regulation of the potential of the spark is essential, however, since great irregularities in time occur when the apparatus is not operated at the same potential, the spark occurring earlier or later than the transit of the bullet across the plate. This, of course, precludes satisfactory records when working with modern high-speed bullets. When the proper potential has been attained a signal light is automatically turned on.

No lens system is employed in the apparatus. An arrangement which has been found very satisfactory places all of the photographic apparatus, except the trigger, inside a small light-tight house.

The trigger itself is located outside the house and near the trajectory. This trigger is an interrupter of the type used by the French in connexion with the Joly chronograph. The use of this instrument and the type of springs used in the photographing-spark-switch were suggested by Dr. D. C. Miller, of the Case School of Applied Science, where the apparatus was developed. The trigger consists of a metal diaphragm about 2 inches in diameter enclosed in a circular metal box. The diaphragm forms one side of an air-tight enclosure, and on the inside face of the diaphragm is attached a circuit-breaking mechanism. This circuit-breaker functions when the crack wave emanating from the bullet strikes the diaphragm, which in turn throws back a small hammer, thus interrupting the circuit and tripping the photographing-spark-switch, with which it is connected in series.

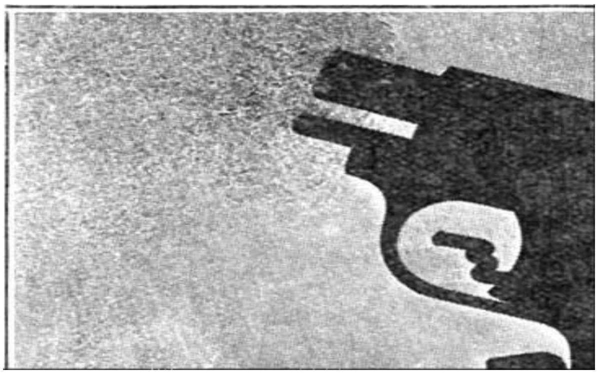

FIG. 2.—Automatic pistol; empty cartridge case just emerging from the receiver.

The essential parts of the photographic apparatus consist of a large Leyden jar battery charged by a static machine which is motor driven, the control switch for the motor being mounted on the table with the rifle. A potential regulator which is connected across the battery functions when the proper potential has been reached, and trips a switch which disconnects the battery from the charging machine and short-circuits the terminals of the latter. The switch when tripped turns on a signal light located outside the apparatus house as a signal to the rifle operator to fire.

When operating the apparatus the general sequence of events is as follows:

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The photographing-spark-switch and battery-switch inside the apparatus house are set, the lights turned out, and the slide of the plateholder drawn. The operator then leaves the apparatus house by means of a light-tight passage and starts the static-machine motor by closing the table switch. He then makes any necessary correction to the aiming and fires when the signal light appears. The bullet leaves the rifle and on its way to the apparatus house passes the trigger upon the diaphragm of which the sound wave impinges. This immediately trips the photographing-spark-switch and it starts to close the trigger gap in the spark circuit. The bullet continues on past the trigger, entering the apparatus house through a sheet of thin paper, used to shut out the light, and arrives in front of the photographic plate, upon which it is then projected by the photographing spark. The motor switch is then opened and the slide replaced in the plateholder, which may then be taken to the dark room and developed.

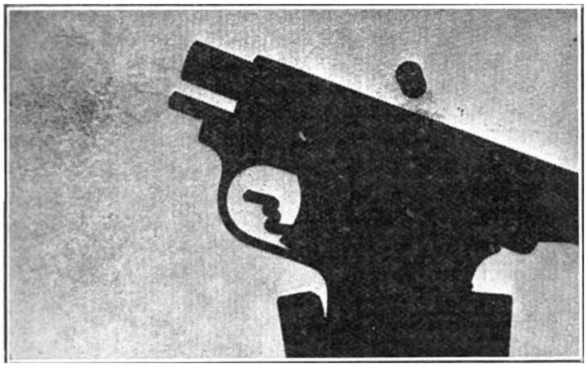

FIG. 3.—Automatic pistol; empty cartridge case ejected from receiver.

In case the speed of the bullets to be photographed is not known, a piece of paper or wire screen is placed in the path of the bullet in front of the photographic plate, and if a puncture in the screen is shown when the plate is developed, evidently the bullet had gone past the plate before the spark occurred. The trigger must then be moved back from the plate and the process repeated. Continuing in this manner the position of the bullet when the spark occurs will soon be bracketed within limits sufficiently small, so that an observer inside the apparatus house may see the bullet as the spark illuminates it. Visual adjustment only is then used until most of the bullets are seen in the desired locality when the spark occurs.

The apparatus is provided with two light gaps, one horizontal and the other vertical. This arrangement facilitates the taking of two photographs of the same bullet, a plan and elevation view. This is particularly useful in investigating a projectile of an unstable character having a tendency to tumble, since from the two views its actual position in space may be constructed.

The two coaxial waves which the bullet propagates from its nose and base appear on the photograph (Fig. 4) to have different slopes. This arises from the projection, for while the axis of the wave is parallel to the photographic plate, and therefore projected in proportion to its length, the radius of the projected wave is somewhat inclined to the plate and causes the distortion. The true angle of the conical sound wave in air may, however, be readily computed, from which the speed of the bullet producing the wave may be determined.[1]

In obtaining the photographs of the Colt automatic 25-calibre pistol, reproduced in Figs. 1, 2, and 3, the interrupter trigger was removed from the circuit and a timing device substituted, which consists of two electromagnets connected in series and adjustable in height, their function being to drop two steel balls at the same time when the key opening their circuit was depressed. One of these balls fell on a lever which pulled the trigger T of the automatic pistol by exerting tension on the arm A (see Fig. 1). The other ball, released from a greater height at the same time as the first, impinged on a device setting off the photographing spark. By this means any reasonable lag or lead in the firing of the pistol with respect to the occurrence of the photographing spark could be obtained. The firing apparatus is obviously not a precision instrument and could, of course, be replaced by an accurate timing device should the investigator require information of such a character.

The turbulent gases of the propelling charge are clearly shown in Figs. 1, 2, and 3. All these photographs of the automatic pistol represent a stage in the recoil relatively long after the ejection of the bullet from the muzzle, since it will be seen that the receiver R has reached the position of extreme recoil and the empty cartridge case is being ejected in Figs. 2 and 3.

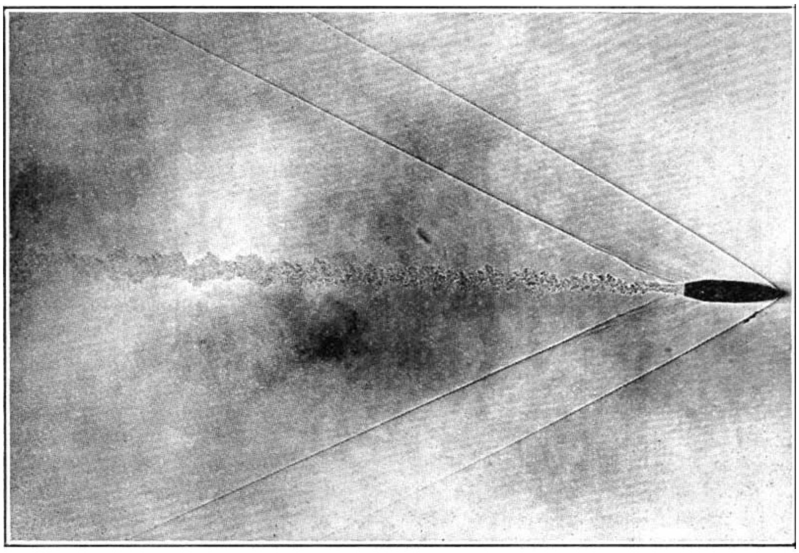

FIG. 4.—30 Calibre boat-tailed bullet, approximate speed 2600 feet per second.

If the height of the ball which triggers the spark is changed progressively by some small known amount, a series of photographs of such an automatic pistol at slightly different calculable time intervals could be secured. From the data obtainable from such photographs a pressure time curve could be computed.

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[1] Journal of the Franklin Institute, May 1922.

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